In-Mixing from the Extra-tropics: Tracer Diagnostics

Laura Pan

Lateral boundary conditions of TTL?

June 2010, Lhasa

Influence of the Extratropics to the Tropical UT & LS

- **A long line of studies**
  - Pierrehmbert et al.
  - Waugh and Polvani (2000)
  - Focus on lower level (215 hPa 350K)
  - RWB as the mechanism
  - Winter Maxima (DJF)
- **Recent study at the tropical tropopause level**
  - Konopka et al., 2010
  - Role of Asian Monsoon anticyclone
  - Summer season (JJA)

Waugh and Polvani, 2000

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Climatology of Intrusions into the Tropical Upper Troposphere

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Abstract. Regions of upper tropospheric equatorial westerly winds, observed over the Pacific and Atlantic Oceans during northern fall to spring, are important for extratropical-tropical interactions. This paper focuses on one feature of these "westerly ducts" that has received relatively little attention to date: the occurrence of Rossby wave breaking events that transport tongues of extratropical air *deep* into the tropics, mix tropical and subtropical air, and can affect deep convection. A climatology of these "intrusion" events formed from 20 years of meteorological analyses shows a strong dependence on the basic-state flow. Notably, intrusion events are found to occur almost exclusively within

zonally and amplifying meridionally as it enters the weak zonal winds north of the Pacific westerly duct (see Figure 1a). This leads to the generation of a thin tongue of high PV intruding into the tropics (Figure 1e), that lasts 2 days. As this intrusion decays, another event can be seen beginning upstream (Figure 1f, 220°E). Intrusion events which transport stratospheric air *deep* into the tropical UT, such as the one presented here, are special cases of the more general wave breaking events along the subtropical tropopause examined by *Postel & Hitchman* [1999].

Because of their penetration deep into the tropics, intrusion events can potentially have a large impact on the UT

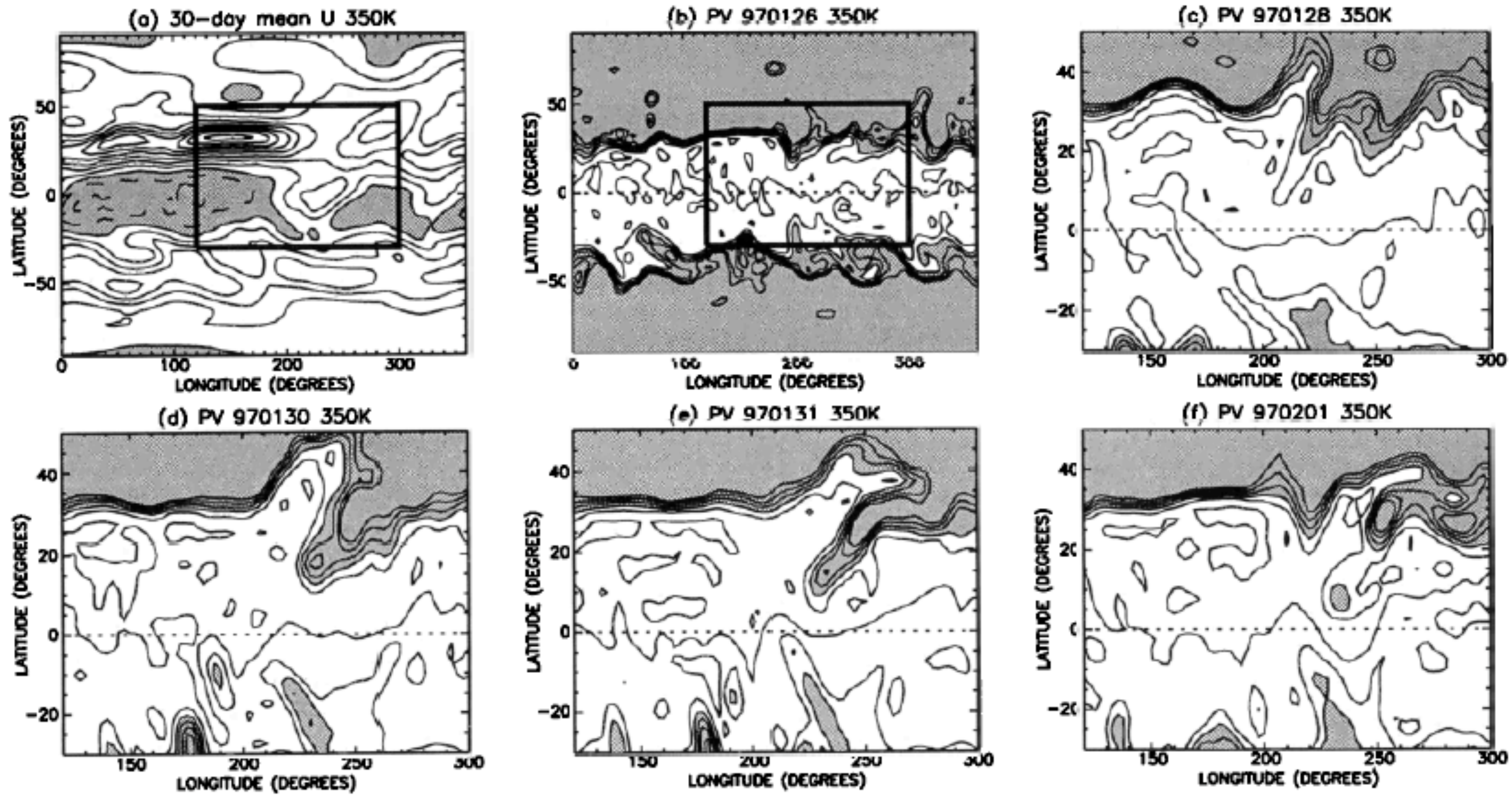

Figure 1. (a) zonal wind averaged between January 16 and February 14, 1997 (contour interval 10 m/s; negative values shaded). (b-f) PV on January 26 to February 1, 1997 (PV = (-5, -4, ..., 5) PVU contoured, with $|PV| > 2$ PVU shaded). All fields are on the 350 K isentrope.

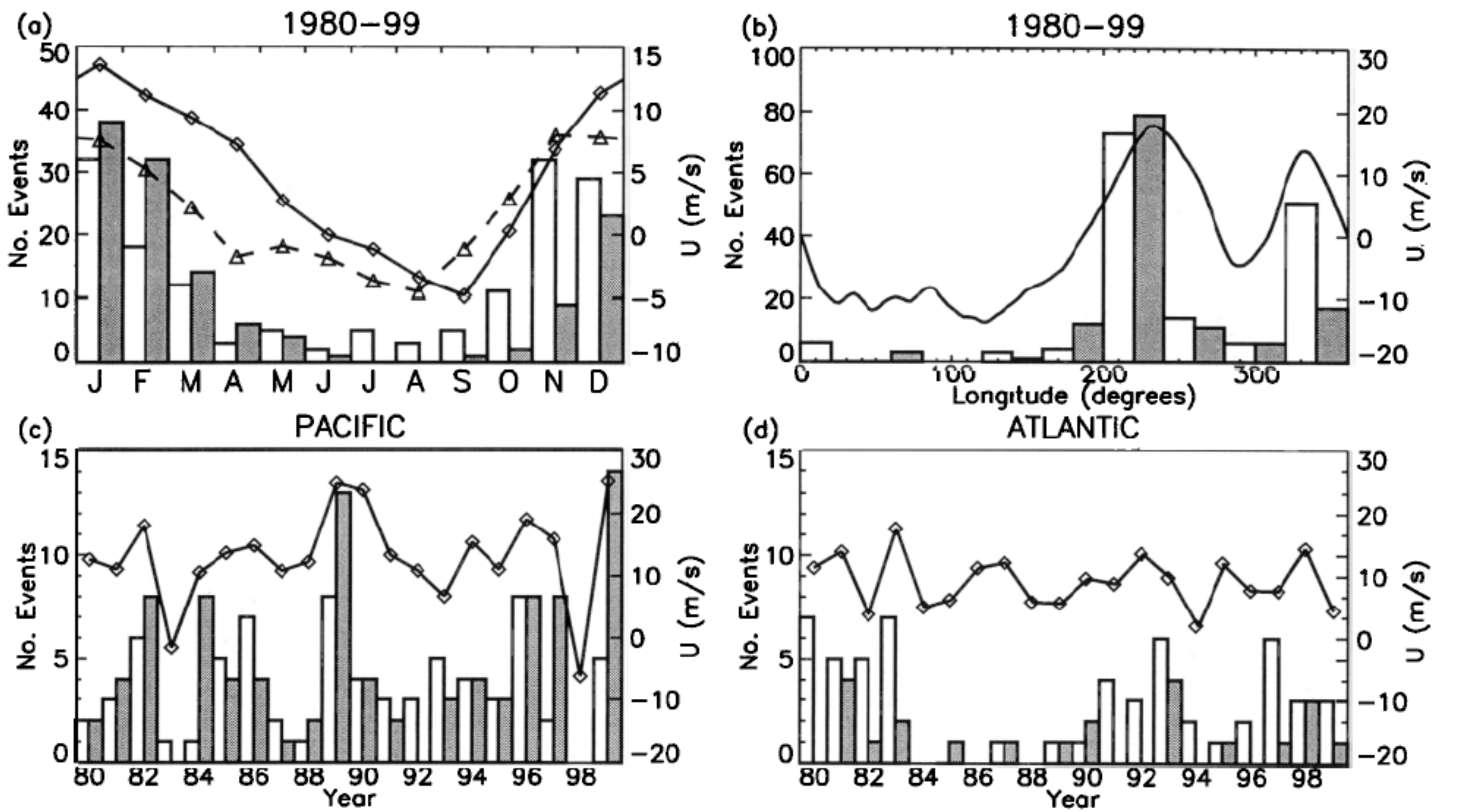

Figure 2. Histograms showing the number of intrusion events per (a) month, (b) longitude, and (c, d) year (NDJFM winter) for Pacific and Atlantic events, respectively. Note that in (c) and (d) "80" corresponds to the 1979/80 winter. The solid (unfilled) bars show northern (southern) hemisphere events. Curves correspond to climatological equatorial zonal winds at 350 K: (a) solid (dashed) curve is average over the Pacific (Atlantic) ocean, (b) DJF average, (c) average over Pacific, and (d) average over Atlantic.

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Impact of potential vorticity intrusions on subtropical upper tropospheric humidity

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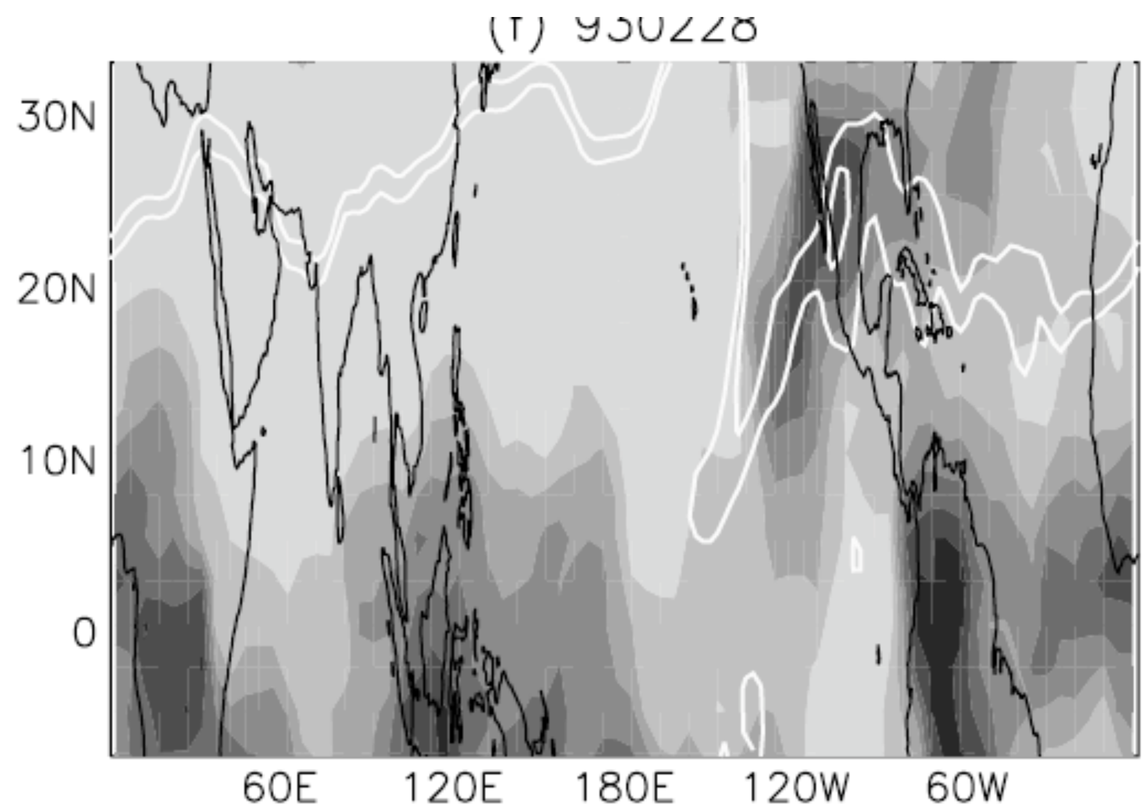
[1] The impact of Rossby wave breaking on the subtropical tropopause and intrusions of high potential vorticity air into the tropical upper troposphere (UT) on subtropical



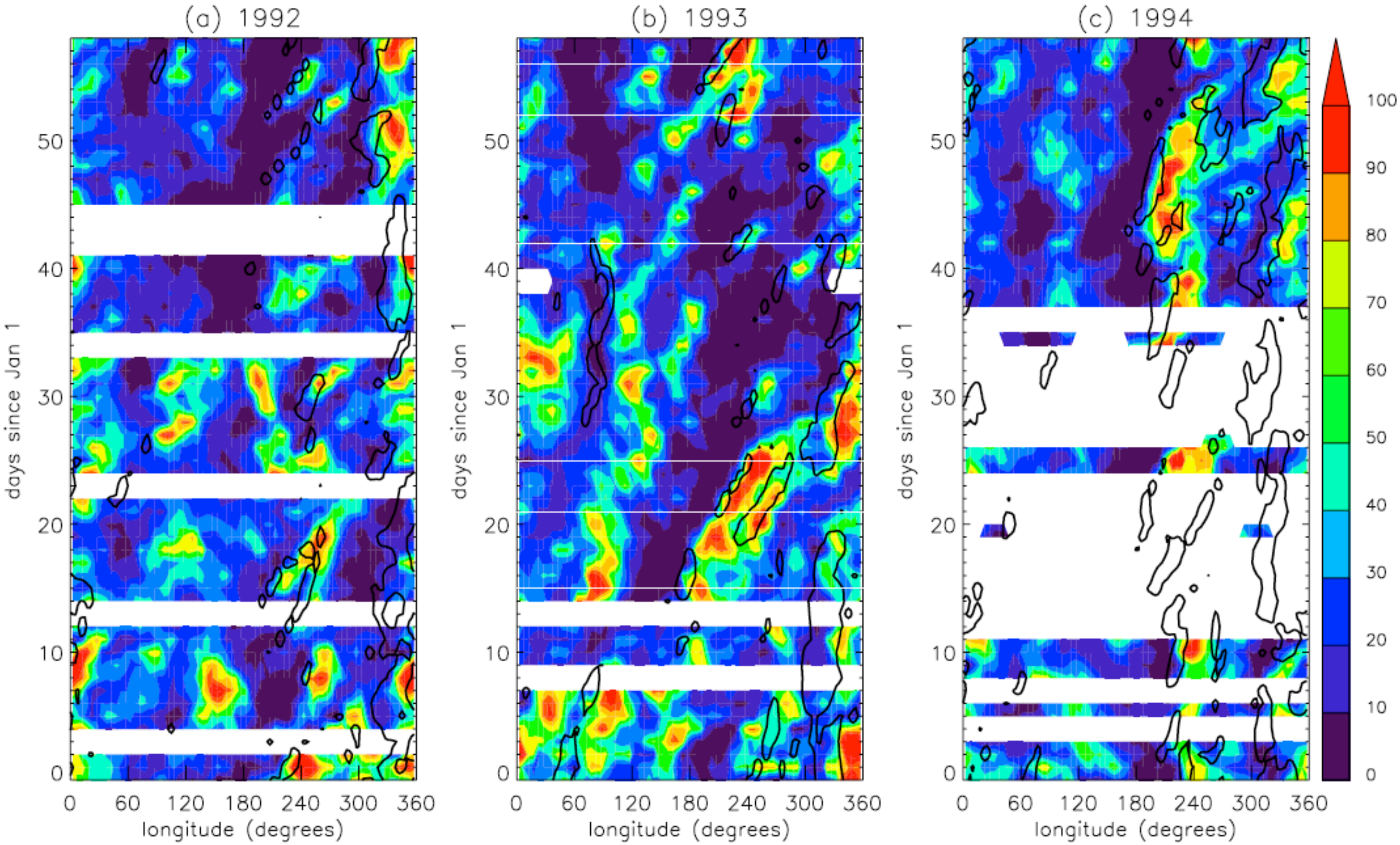


Figure 2. Longitude-time variation of MLS 215 hPa RH at 16.25°N for January–February in 1992, 1993, and 1994. Contours show PV = 1.5 PVU at 17.5°N. White horizontal lines in Figure 2b mark dates shown in Figure 1.

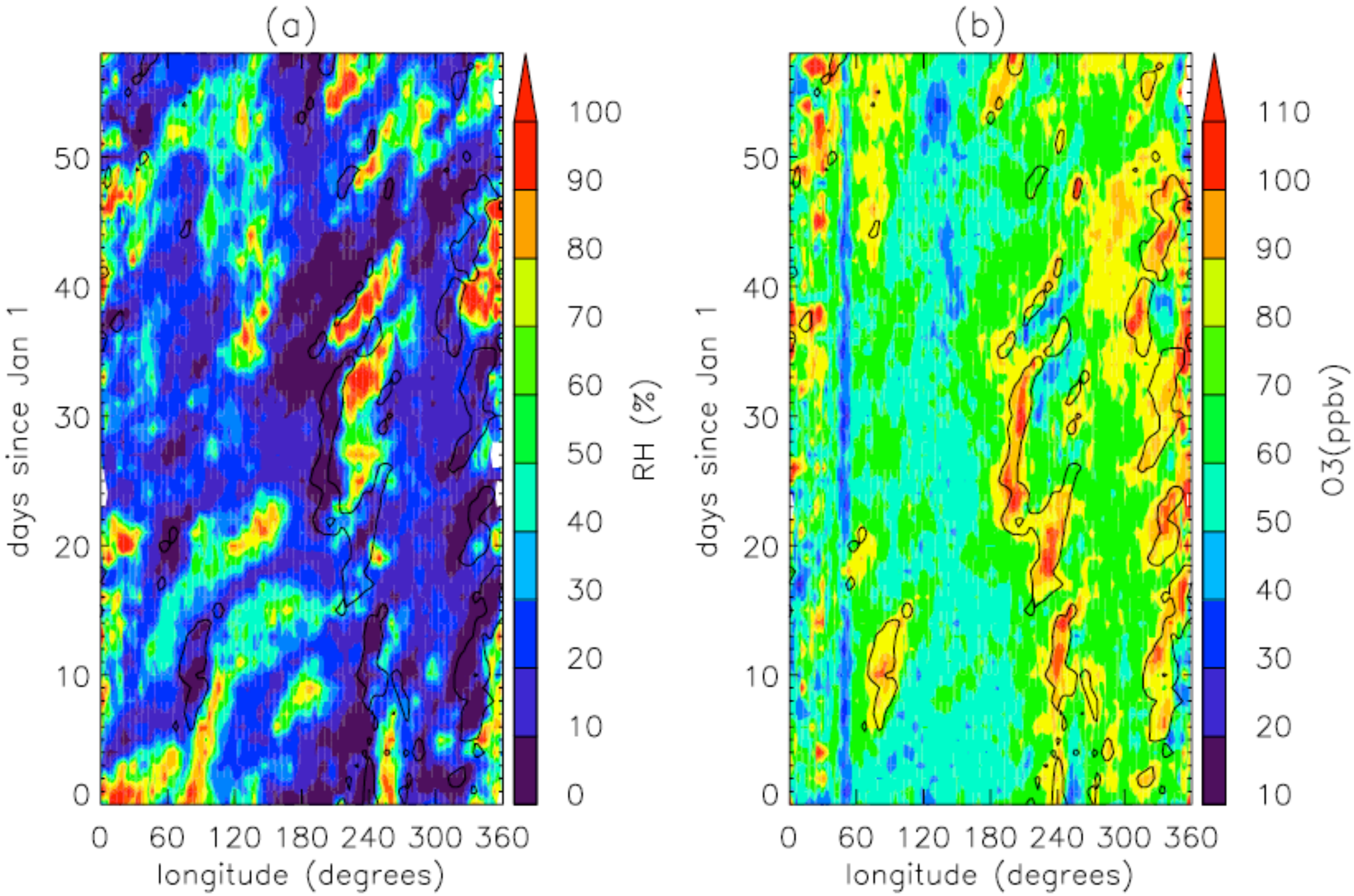
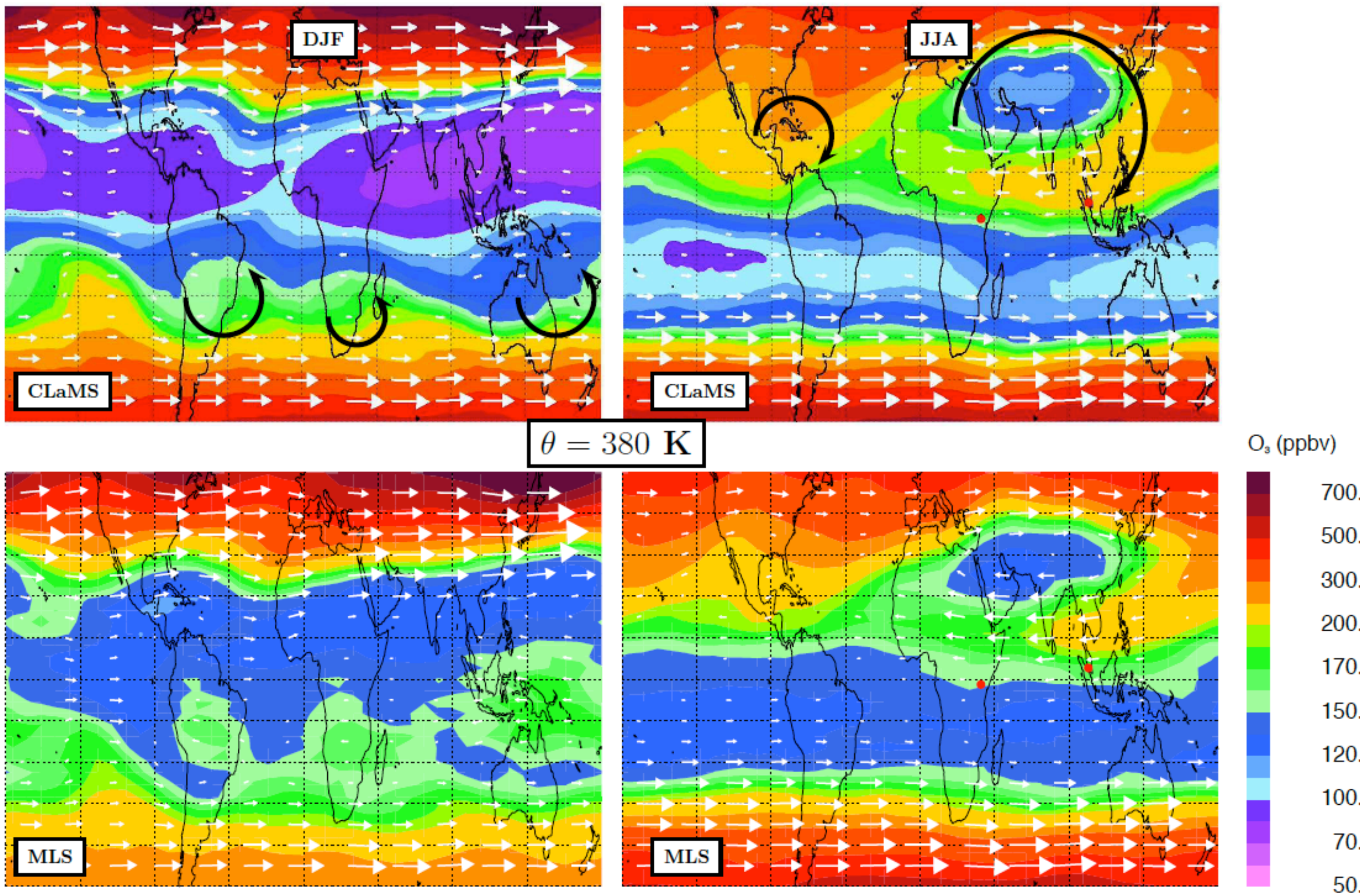


Figure 3. Longitude-time variation of AIRS 200–250 hPa (a) RH and (b) O_3 mixing ratios at 17.5°N for January–February in 2004. Contours show PV = 1.5 PVU at 17.5°N.

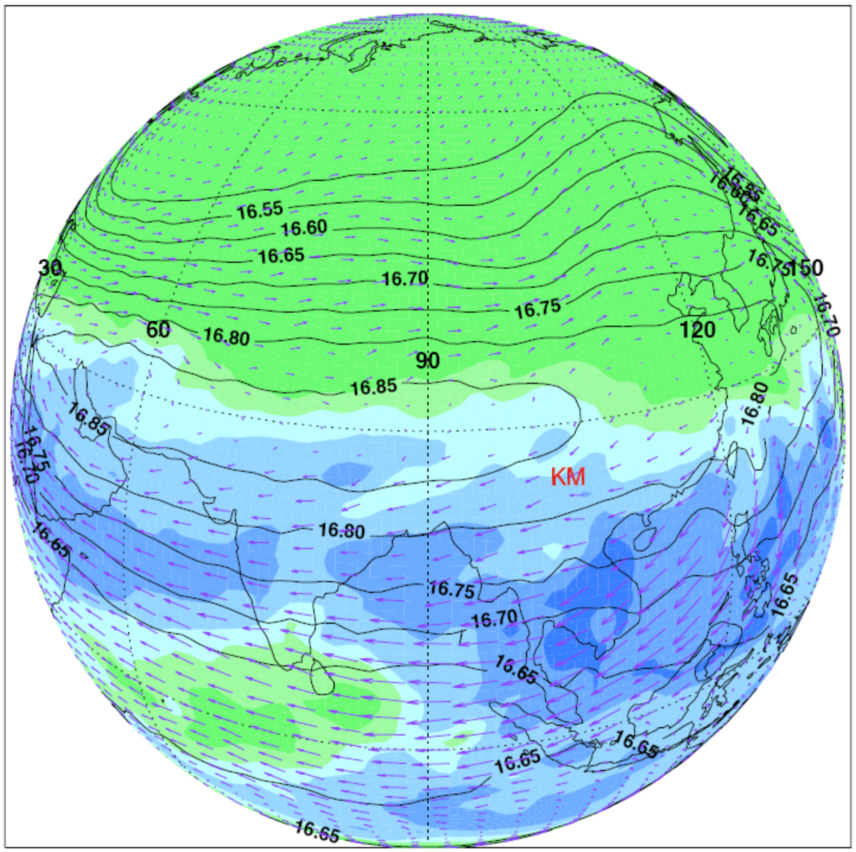
Term "In-Mixing" Konopka et al 2010



Example from KunMing Campaign

Jianchun Bian (IAP/CAS, China), Holger Voemel et al., 2009

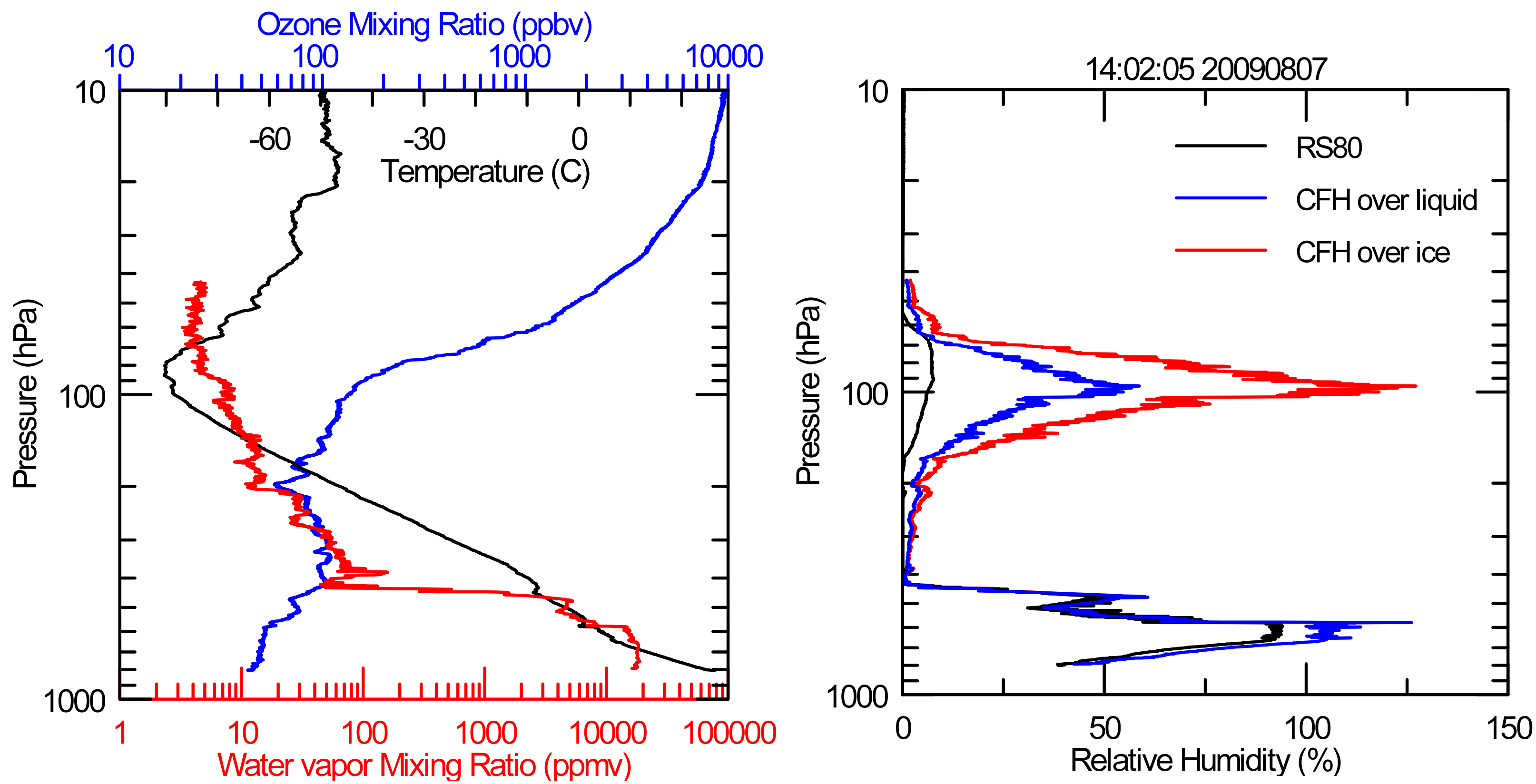
T, Wind and Hgt 100 hPa, 20090808 06 UTZ



Asian Monsoon Study

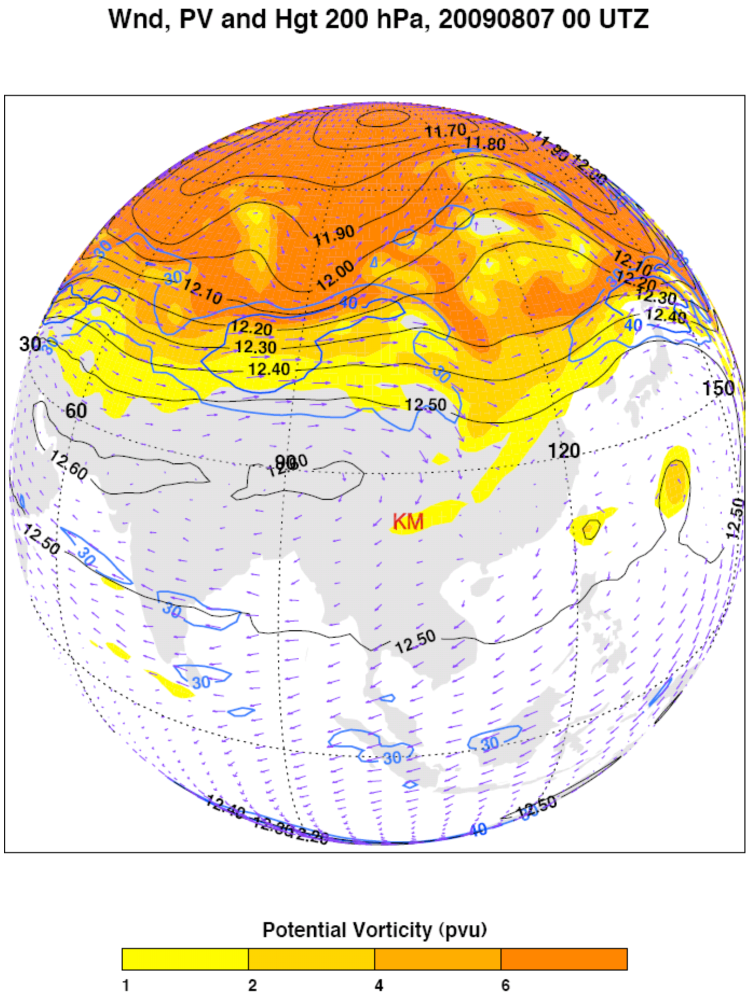
- August 2009
- KunMing, China (25°N, 102°E)
- Ozone and water vapor (CFH)
- 11 profiles

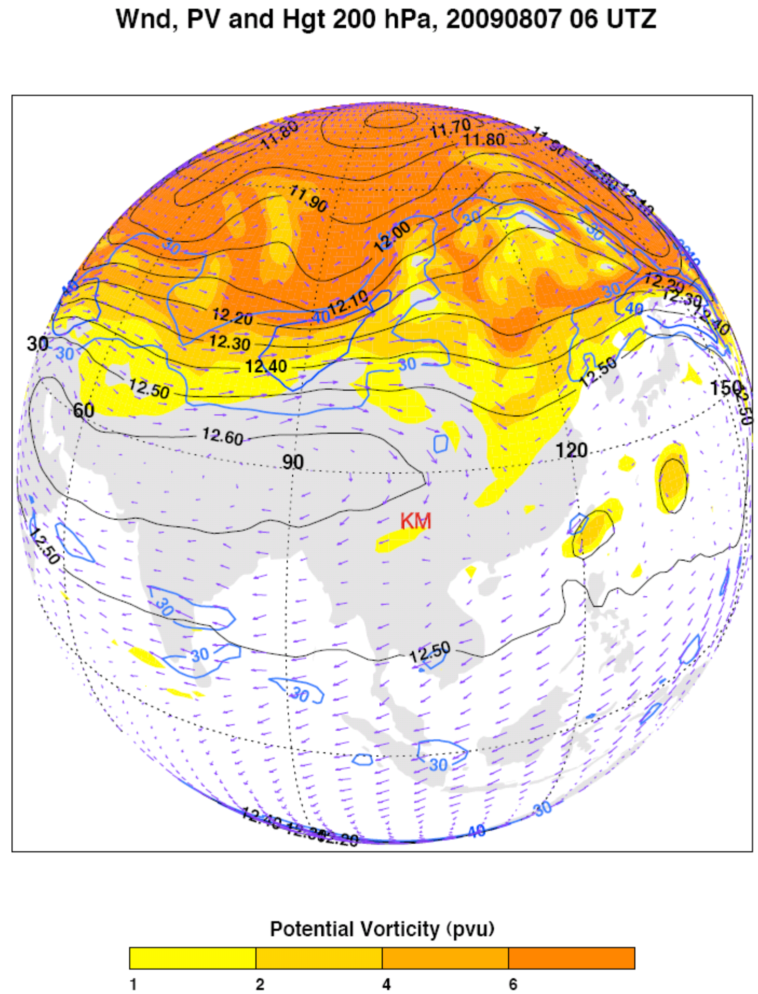
Case 2 Extra-Tropical Stratospheric Intrusion

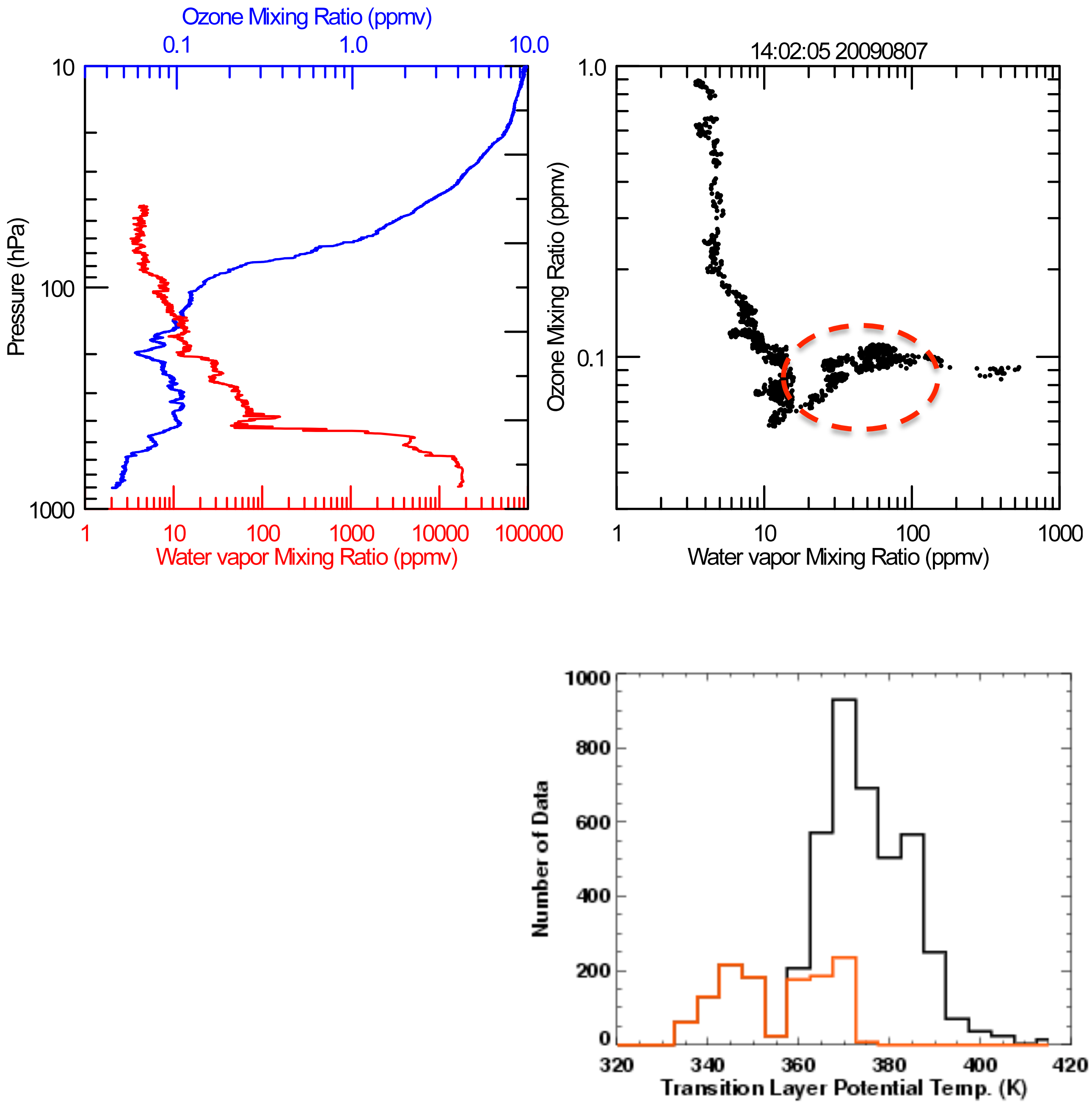


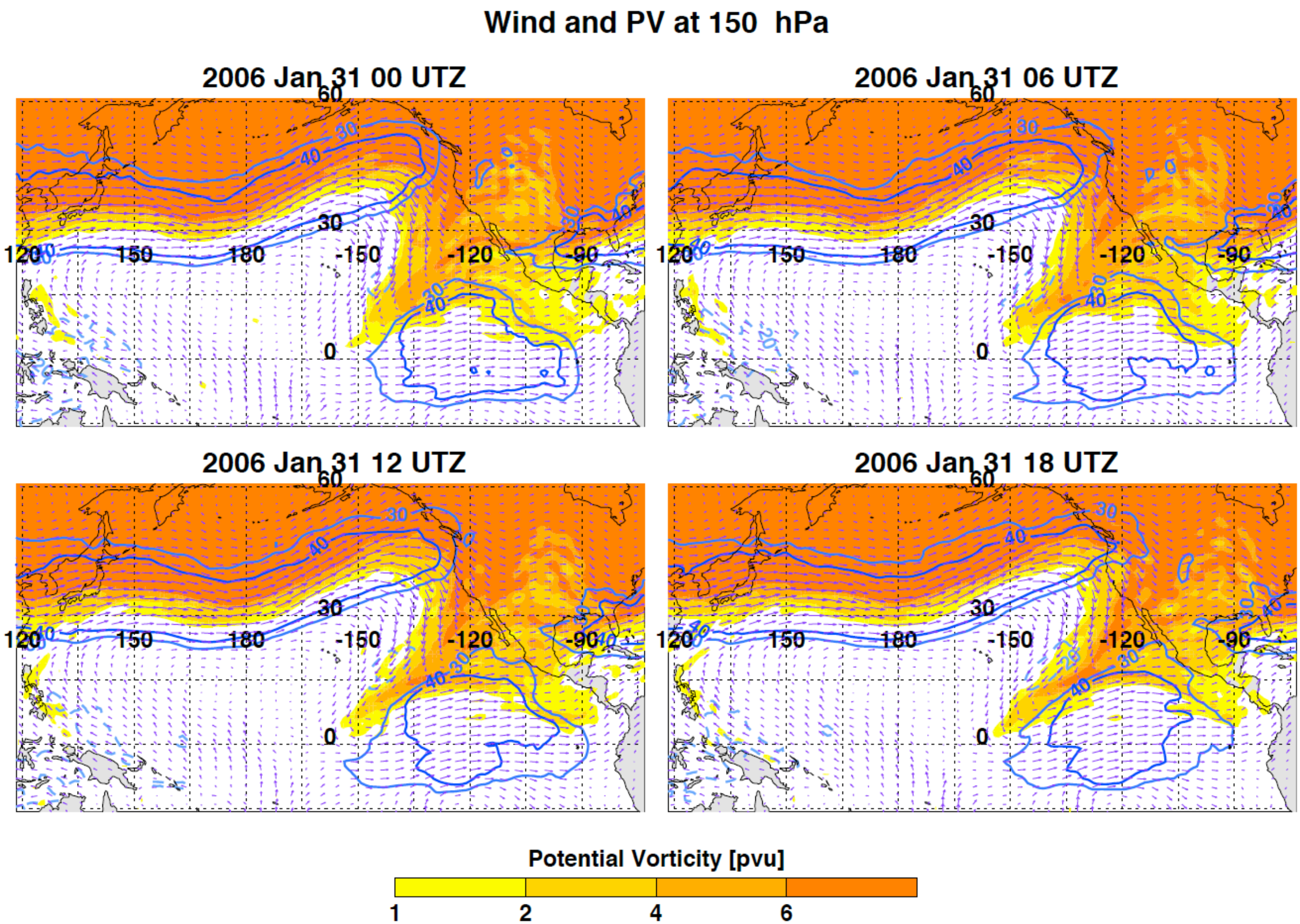
✓Thick dry and high-O3 layer in mid-troposphere

Mechanism: Stratospheric Intrusion






Ozone Mixing Ratio (ppmv)
0.1
1.0
10.0
10
100
1000
Pressure (hPa)
1
10
100
1000
10000
100000
Water vapor Mixing Ratio (ppmv)
14:02:05 20090807
1.0
0.1
Ozone Mixing Ratio (ppmv)
1
10
100
1000
Water vapor Mixing Ratio (ppmv)
1000
800
600
400
200
0
Number of Data
320
340
360
380
400
420
Transition Layer Potential Temp. (K)


Wind and PV at 150 hPa
2006 Jan 31 00 UTZ
2006 Jan 31 06 UTZ
2006 Jan 31 12 UTZ
2006 Jan 31 18 UTZ
60
30
0
120
150
180
-150
-120
-90
Potential Vorticity [pvu]
1
2
4
6